
Status of Run II and Plans for FY04

Accelerator Advisory Committee Review

November 19, 2003

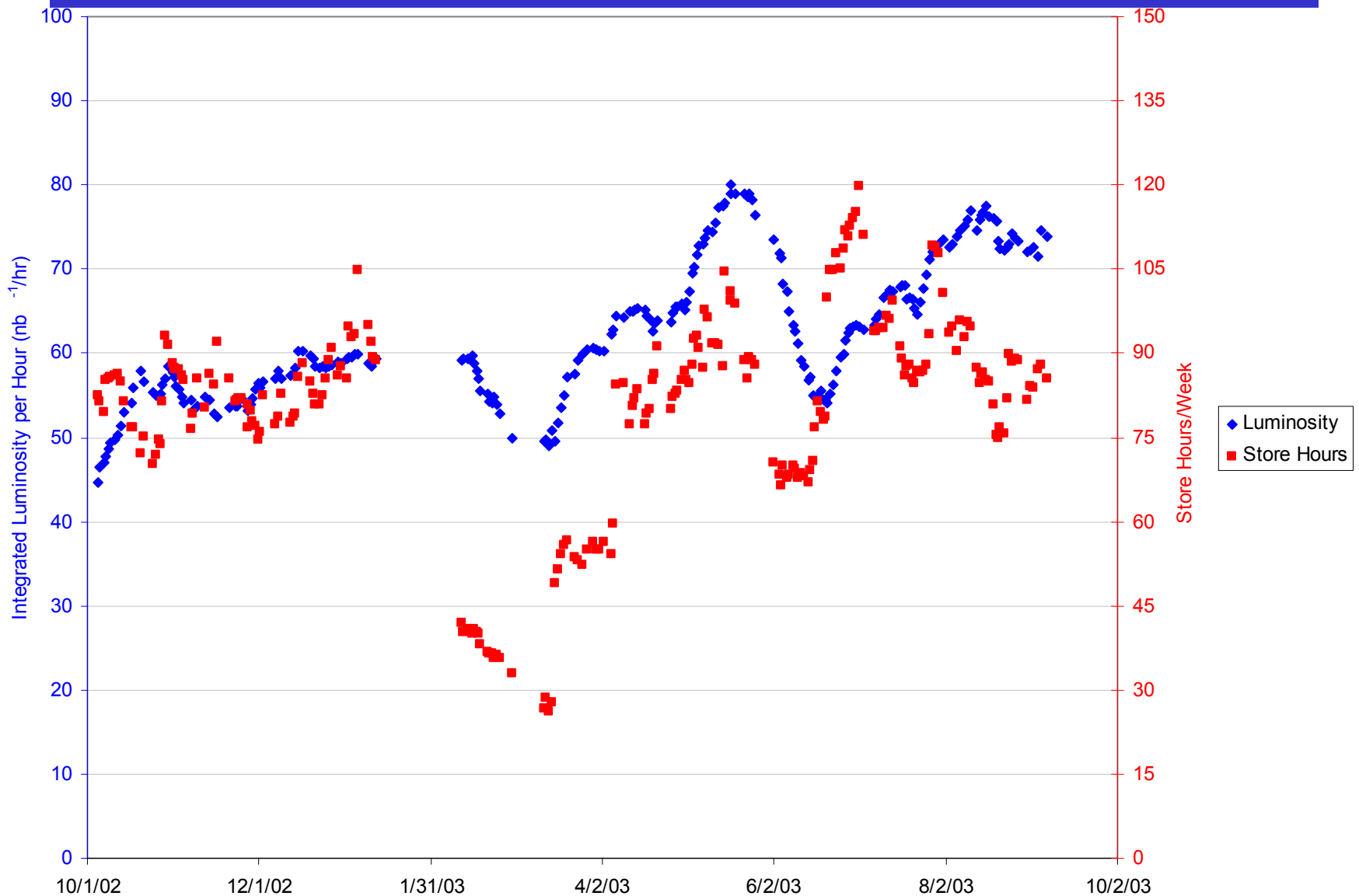
Dave McGinnis

Outline

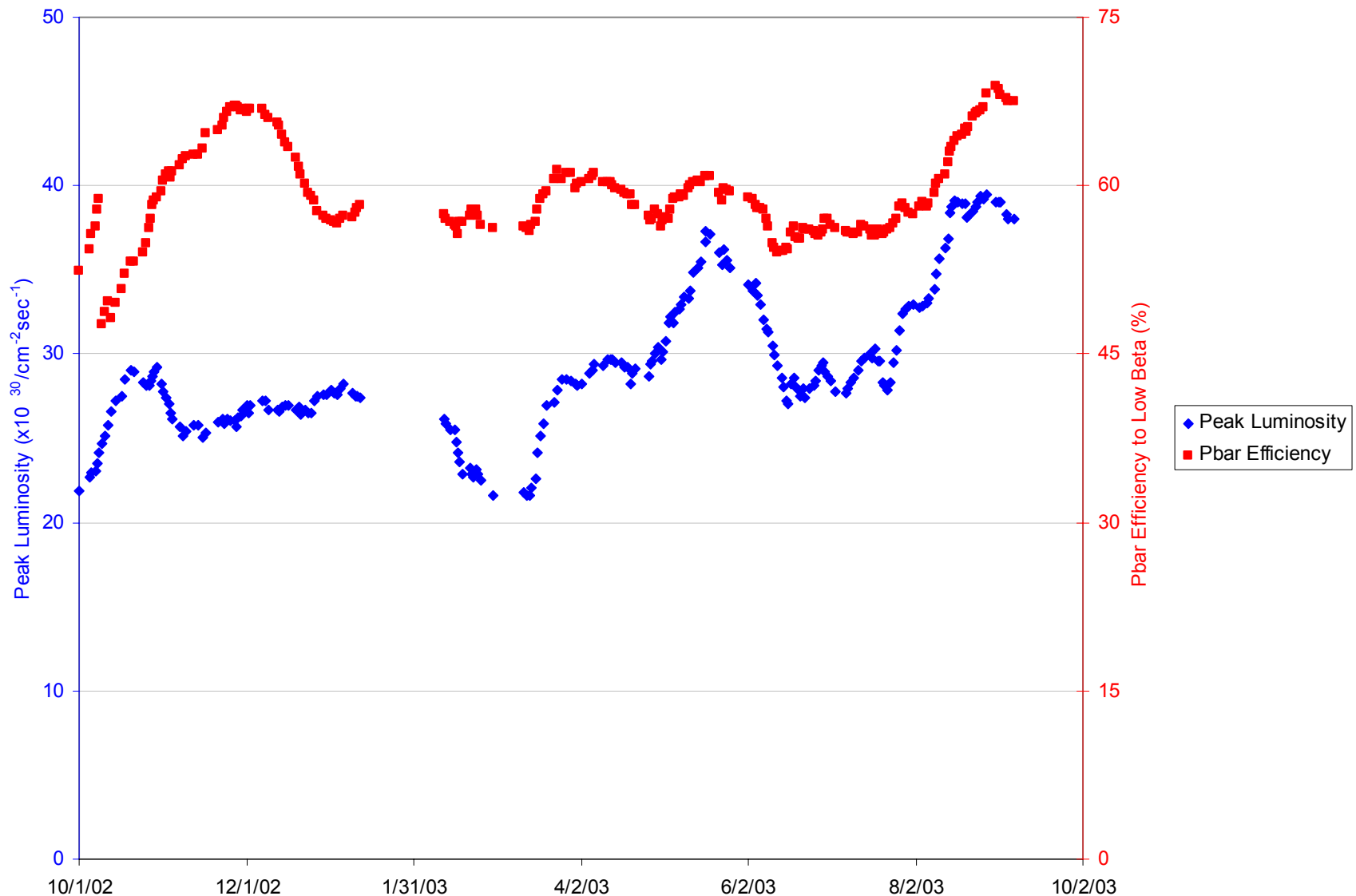
- FY03 Performance
- Accelerator Issues
 - TEV
 - Pbar
 - Main Injector
 - Reliability
- FY04 Luminosity Parameters
- Operations
 - Study Strategy
 - Shot Strategy
- Accelerator Coordination
- Summary

FY03 Performance

FY03 Performance



FY03 Performance



FY03 Performance

Parameter	Last Store	Last 10 stores Average	Last 10 stores St. Dev.	Last 50 stores Average	Last 50 stores St. Dev.	
Initial Luminosity (Average)	40.2	37.5	4.6	36.1	6.5	$\times 10^{30} \text{cm}^{-2} \text{sec}^{-1}$
Integrated Luminosity per Store (Averaged)	1510.3	1053.0	396.9	1088.9	495.7	nb^{-1}
Luminosity per week (Averaged)	-	5.6	-	6.4	-	pb^{-1}
Store Length	19.9	14.1	5.4	14.9	6.7	Hours
Store Hours per week	-	75.5	-	87.8	-	Hours
Shot Setup Time	2.5	2.2	0.3	2.3	0.6	Hours
Protons per bunch	238.2	237.3	22.6	237.3	18.8	$\times 10^9$
Proton Efficiency to Low Beta	58.0	59.9	3.4	58.3	4.7	%
Antiprotons per bunch	22.6	22.5	3.0	22.2	2.6	$\times 10^9$
Start Stack	118.8	134.6	26.5	144.3	22.1	$\times 10^{10}$
End Stack	11.8	14.8	5.4	16.5	11.0	$\times 10^{10}$
Unstacked Pbars	107.0	119.8	24.0	128.2	19.6	$\times 10^{10}$
Pbar Transfer efficiency to Low Beta	76.0	68.5	6.3	63.3	7.7	%
HourGlass Factor	0.63	0.64	0.01	0.63	0.01	

FY03 Performance

Efficiency	Last Store	Last 10 stores Average	Last 10 stores St. Dev.	Last 50 stores Average	Last 50 stores St. Dev.	
MI Injection (Pbar)	98.0	97.0	0.7	95.8	3.8	%
MI Acceleration (Pbar)	98.0	99.1	0.6	98.8	0.8	%
Coalescing (Pbar)	95.0	92.8	2.6	92.4	3.2	%
Tev Injection (Pbar)	93.0	91.4	1.0	89.8	2.0	%
TEV Acceleration (Pbar)	96.0	93.5	3.7	91.1	4.8	%
Initiate Collisions (Pbar)	96.0	94.4	2.1	92.0	5.7	%
Unaccounted (Pbar)	97.2	95.1	5.9	95.9	10.0	%
Efficiency	Last Store	Last 10 stores Average	Last 10 stores St. Dev.	Last 50 stores Average	Last 50 stores St. Dev.	
MI Injection (Proton)	90.0	91.4	4.2	91.7	3.8	%
MI Acceleration (Proton)	94.0	98.2	2.2	96.5	13.9	%
Coalescing (Proton)	90.0	88.6	3.5	87.4	3.0	%
Tev Injection (Proton)	94.0	95.1	2.0	94.1	2.0	%
TEV Acceleration (Proton)	93.0	95.2	1.5	95.1	1.2	%
Unaccounted (Proton)	87.1	83.3	2.0	81.7	5.2	%

Accelerator Issues

Run II (without the Recycler) and Run Ib

- Projected - $5.3\times (8.5\times 10^{31}\text{cm}^{-2}\text{ sec}^{-1} / 1.6\times 10^{31}\text{cm}^{-2}\text{ sec}^{-1})$
- Delivered - $2.3\times (3.7\times 10^{31}\text{cm}^{-2}\text{ sec}^{-1} / 1.6\times 10^{31}\text{cm}^{-2}\text{ sec}^{-1})$
- More Pbars
 - projected - 3.3x
 - More protons on target - 2x ($5\times 10^{12}/2.5\times 10^{12}$)
 - Faster Pbar cycle rate - 1.6x ($2.4\text{sec}/1.5\text{sec}$)
 - delivered - 1.9x
 - More protons on target - 1.9x ($4.7\times 10^{12}/2.5\times 10^{12}$)
 - Faster Pbar cycle rate - 1x ($2.4\text{sec}/2.4\text{sec}$)
- More Protons
 - projected - 1.17x ($270\times 10^9/230\times 10^9$)
 - delivered - 1.09x ($250\times 10^9/230\times 10^9$)
- Shorter Bunch lengths
 - projected form factor - 1.25x ($0.37\text{m} \leftarrow 0.6\text{ m}$)
 - delivered form factor - 1.07x ($0.52\text{m} \leftarrow 0.6\text{ m}$)
- Higher Energy
 - projected - 1.11x ($1000\text{ GeV}/900\text{ GeV}$)
 - delivered - 1.09x ($980\text{ GeV}/900\text{ GeV}$)

TEVATRON Issues

- Transverse Emittance Dilution at injection
 - Transmission efficiency to low beta
 - Long range Beam Beam effects - big beam sizes
- Chromaticity control
 - Lifetime at 150 GeV
 - Stability - number of protons at low beta
- Helices
 - Transmission efficiency to low beta
 - Long range Beam Beam effects
- Reliability

TEVATRON Transmission Efficiency

- We made very good progress during the summer of 2003 in increasing the efficiency from 60% to 73% (SBD corrected)
 - S6 circuits and differential chromaticity
 - New high energy helix
 - Accumulator to MI pbar emittance reduction
 - TEV injection lattice corrections
- At first glance, 73% antiproton transmission efficiency from the Accumulator Core to Low Beta seems to be very low.
- However, the 73% transmission efficiency is composed of many stages of transfers each with relatively good efficiency $73\% = (94\%)^5$
- To improve the transfer efficiency to 90%, the average efficiency of each stage of the pbar transfer must increase from 94% to 98%
- Increasing the pbar transfer efficiency from 73% to 90% will increase the luminosity by a factor of 1.23

TEVATRON Projects

- Transverse Emittance Dilution at injection
 - Injection lattice matching for pbars and protons
 - Smart bolt retro-fit (this shutdown)
 - New TEVATRON sextupole (borrowed from Pbar)
 - Injection dampers for pbars
- TEVATRON Chromaticity Control
 - Shielding of the F0 Lamberts
 - Re-wiring of the TEV octupole circuits
- Better TEV Helices
 - Optimized helices at 150 GeV
 - TEV alignment

Emittance dilution at Injection into the TEV

- Injection lattice matching for pbars and protons
 - First pass complete
 - Second pass study time completed
 - Will require new optics for 150 GeV injection lines
 - First pass at TEV injection lattice corrections completed
- Remove coupling
 - Smart bolt retro-fit (this shutdown)
 - New TEVATRON sextupole (borrowed from Pbar)
 - Decoupling injection helical orbits
- Injection dampers for pbars
 - Already installed in early FY04
 - await more commissioning time

TEVATRON Chromaticity Control

- Reduce the Chromaticity
 - Shielding of the F0 Lambertsos
 - Reduces the transverse impedance of the TEV
 - Re-wiring of the TEV octupole circuits
 - Gives more Landau damping
- Reduce the differential chromaticity
 - Re-wiring of the TEV octupole circuits

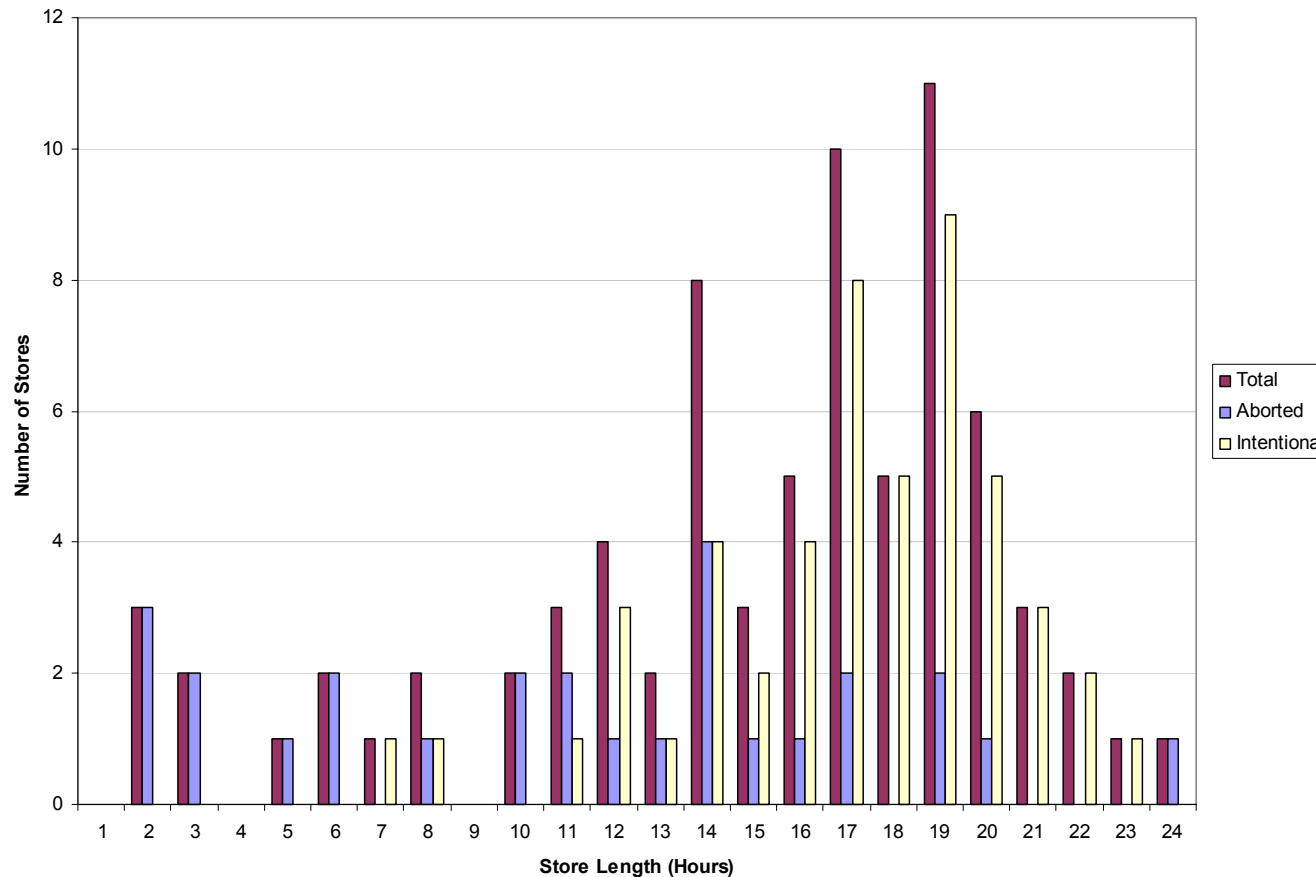
Better TEV Helices

- Optimized helices at 150 GeV - designed - waiting for study time
 - Increases the separation of closest near misses without increasing overall separation
- Bigger and optimized helices up the ramp - installed - waiting for 2nd round of optimization
- Alignment
 - Installed a new alignment network (this shutdown)
 - Reduce the coupling by shimming the smart-bolts in ~100 TEV dipoles (this shutdown)
 - Remove the largest magnet rolls
 - Re-align the TEV magnets where needed

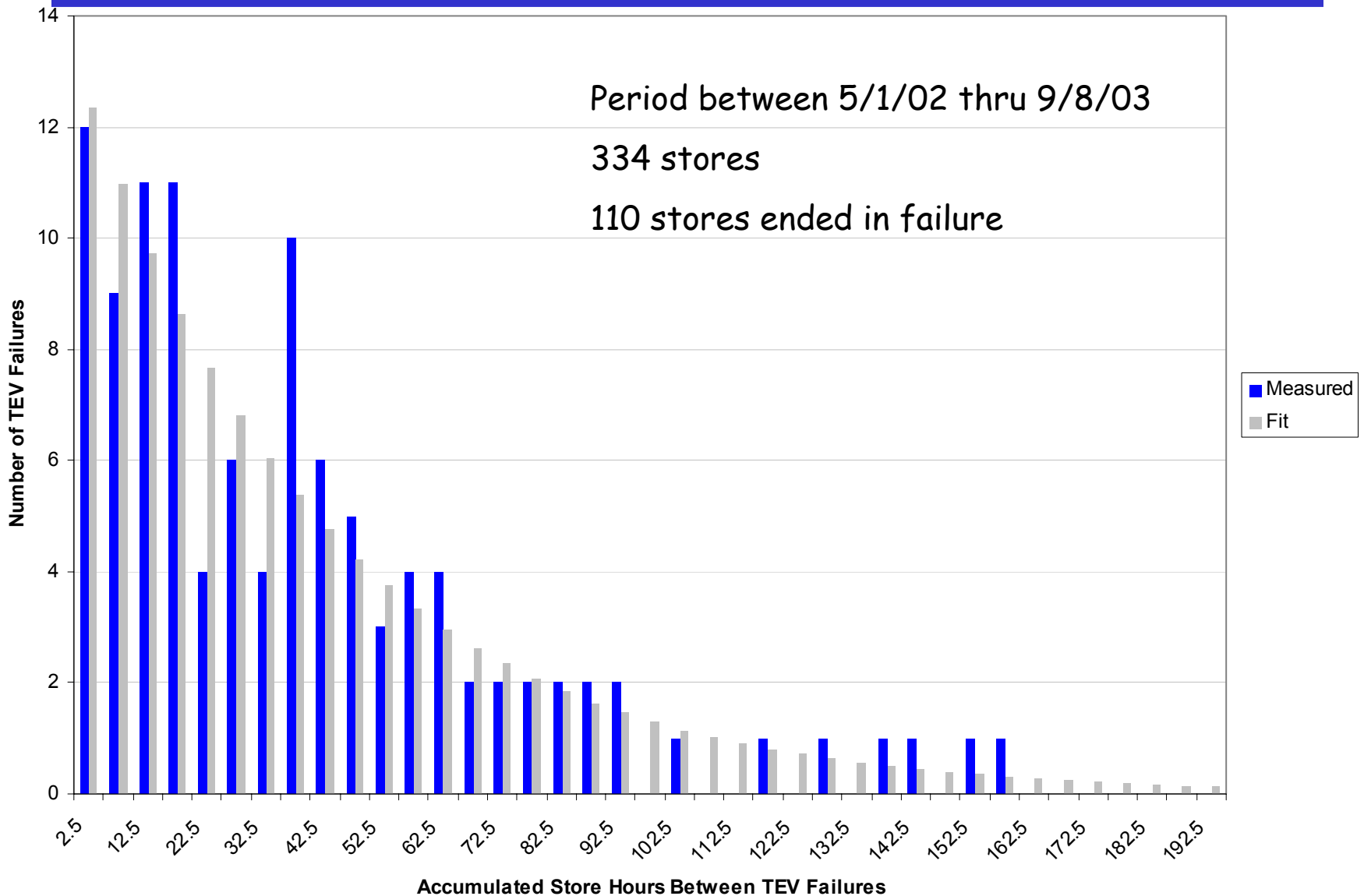
TEVATRON Reliability

- Our highest luminosities were obtained by shooting from large stacks

- These large stacks were obtained by stacking for a long time because the previous store lasted a long time
- Our desire is to run long stores and stack big.
- However, our average store length is limited by equipment failure



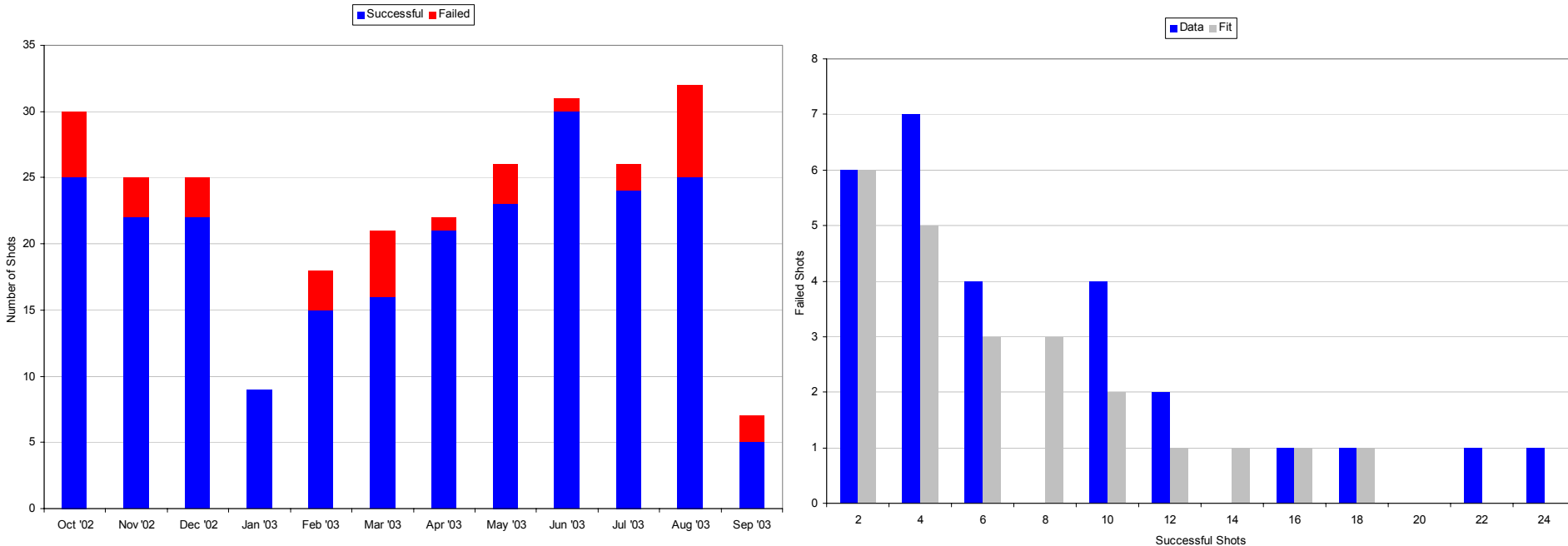
TEVATRON Store Reliability



TEVATRON Store Reliability

- A TEV failure is independent of the time in the store (exponential distribution)
 - The mean number of store hours between failures is 42 hours
 - 42 hours translates to a TEV reliability of 97.6% per hour
 - The probability that the TEV will remain at up for the next hour is 97.6%
- A TEV Reliability of 97.6% predicts that:
 - 1 out of every 4 stores will end in failure if our target store duration is 12 hours
 - 1 out of every 3 stores will end in failure if our target store duration is 17 hours
- Increasing the reliability by 1% will, on average, require the doubling of the lifetime of TEV components

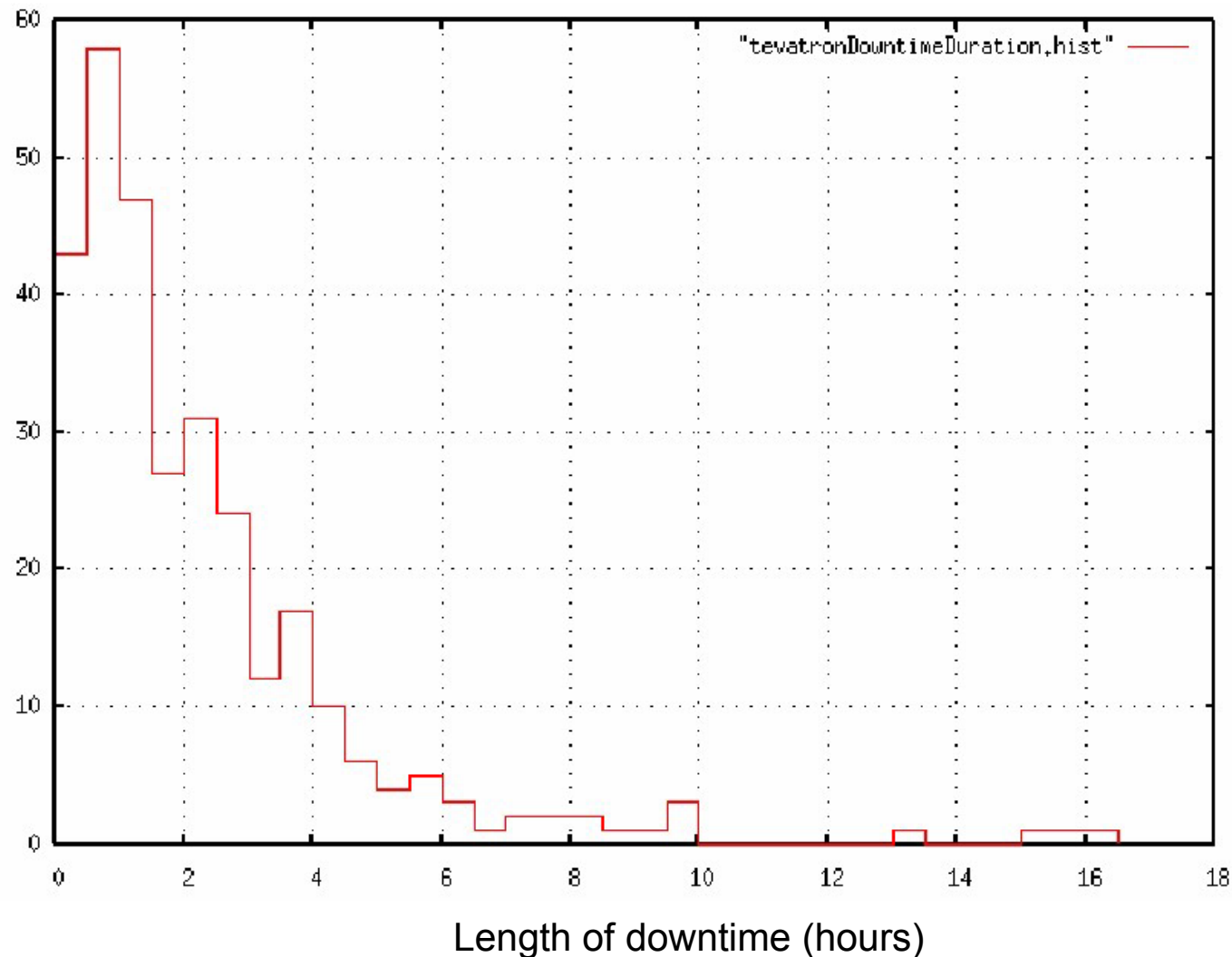
TEVATRON Shot Reliability



- The number of shots that made it successfully to HEP in FY03 is 237 out of 272 attempted (87%)
- The mean number of successful shots between failed shots is 7
 - The reliability of TEV shots is 85% per shot

TEV Downtime Since 1/1/03

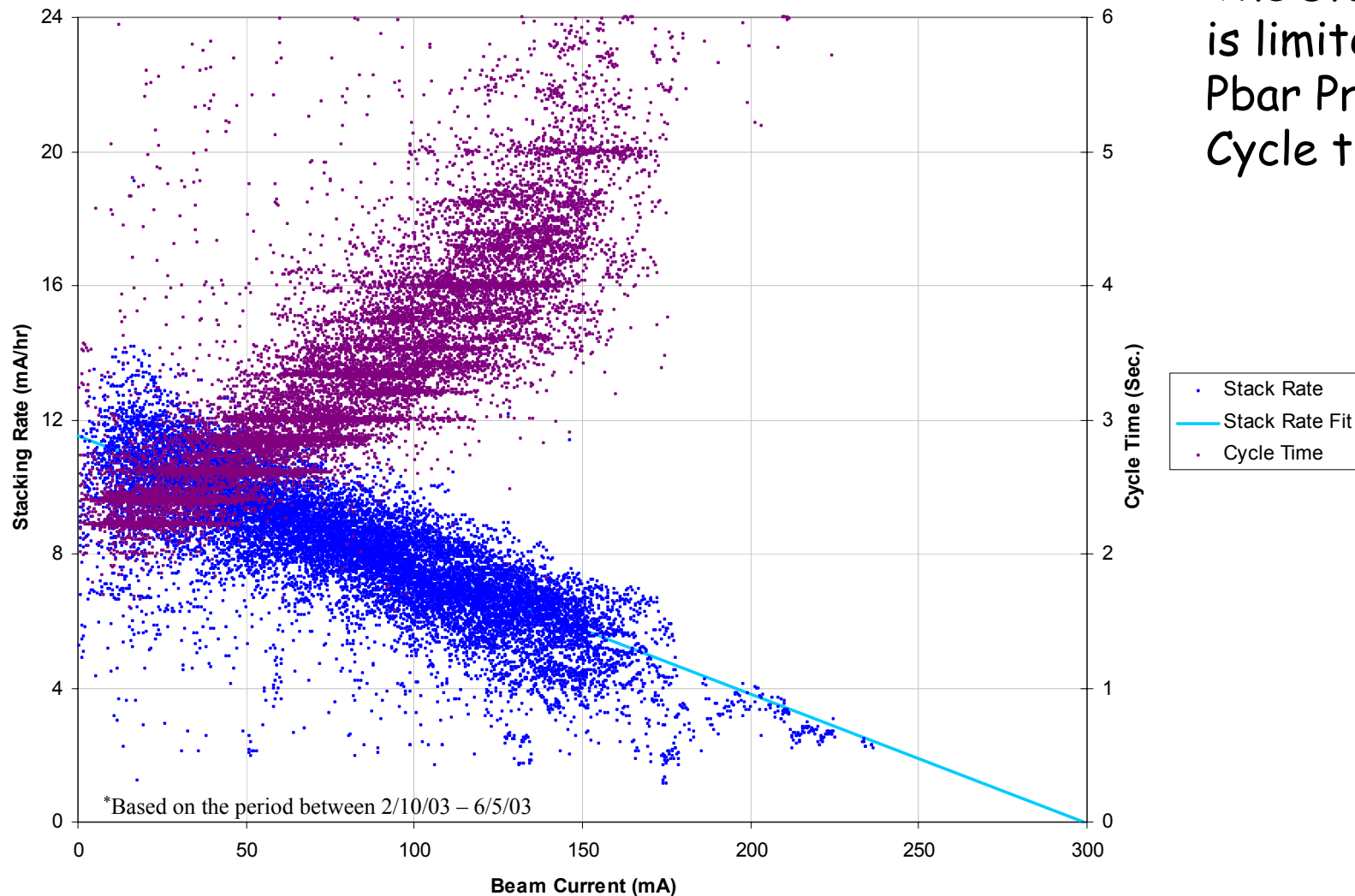
- The length of TEV downtime has an exponential distribution with a mean length of down time equal to 2.2 hours
 - This corresponds to a probability of remaining down at 36.5% per hour



Pbar Production

- Because our average store length is limited by equipment failure:
 - The only way to increase the luminosity significantly in FY04 is to increase the stacking rate.
 - The Pbar stacking rate is limited between “cooling” cycle time
- Pbar Cooling Cycle Projects
 - Debuncher Momentum Cooling Notch Filter Equalizers
 - New Stacktail BAW filters
 - Improved Stacktail crossover
 - Main Injector Beam loading compensation through the entire acceleration ramp
 - Main Injector Longitudinal Dampers

Pbar Stacking Rate

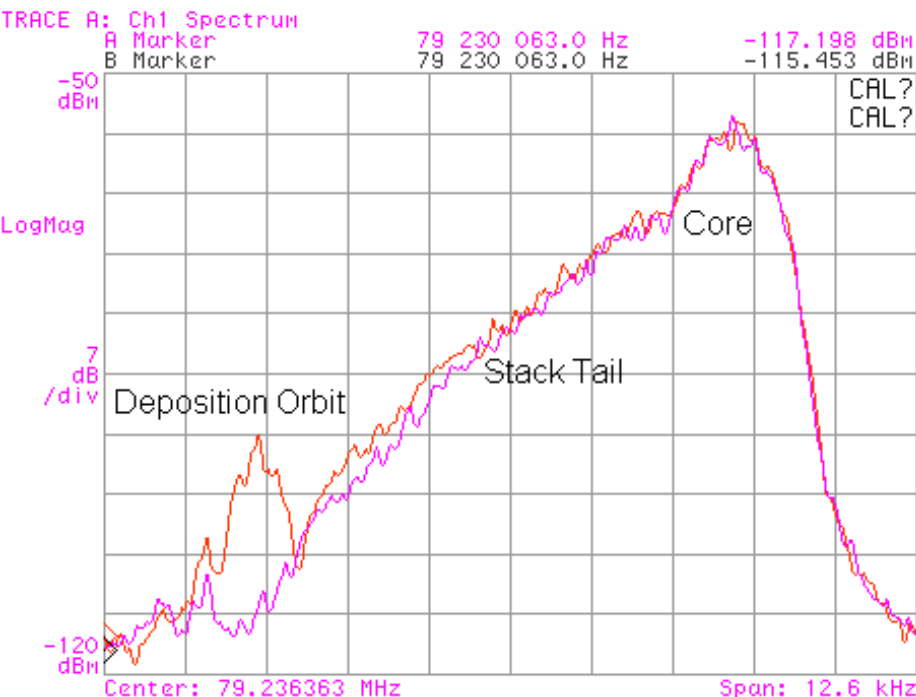


- The stacking rate is limited by the Pbar Production Cycle time

Why is the Cycle Time so Slow?

- Beam must be cleared off the Stacktail deposition orbit before next beam pulse.
 - The more gain the Stacktail has, the faster the pulse will move.

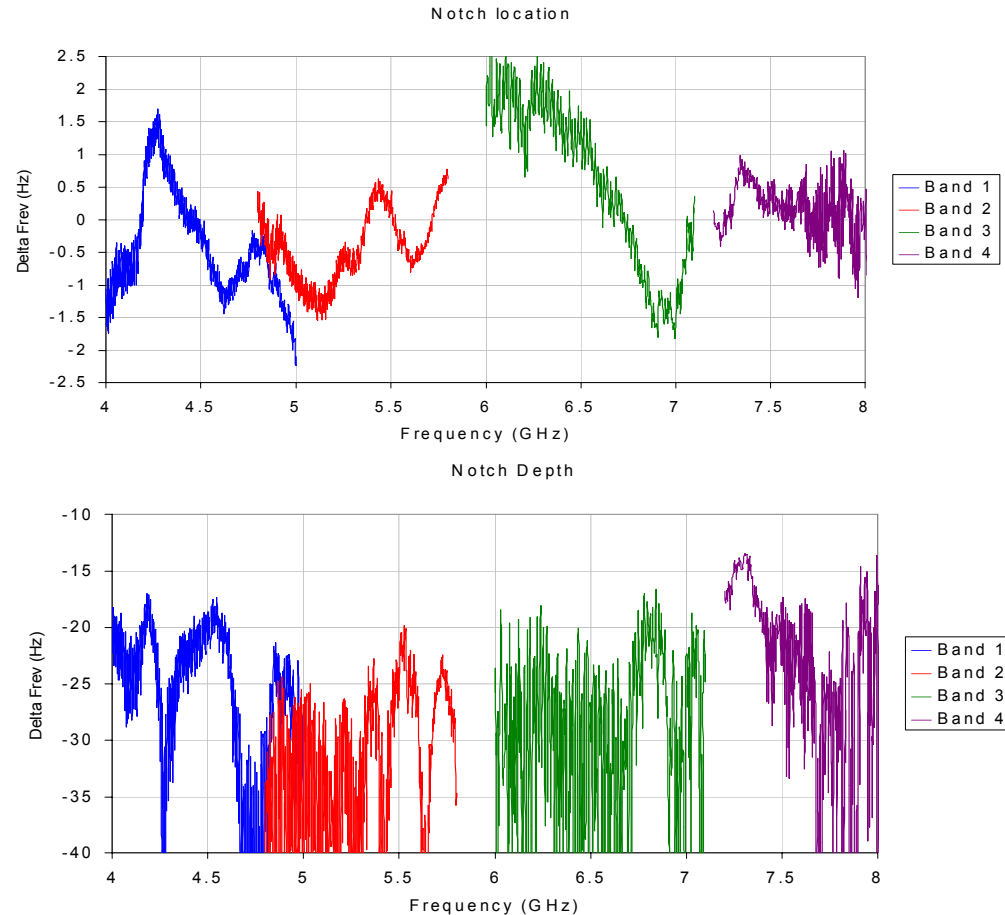
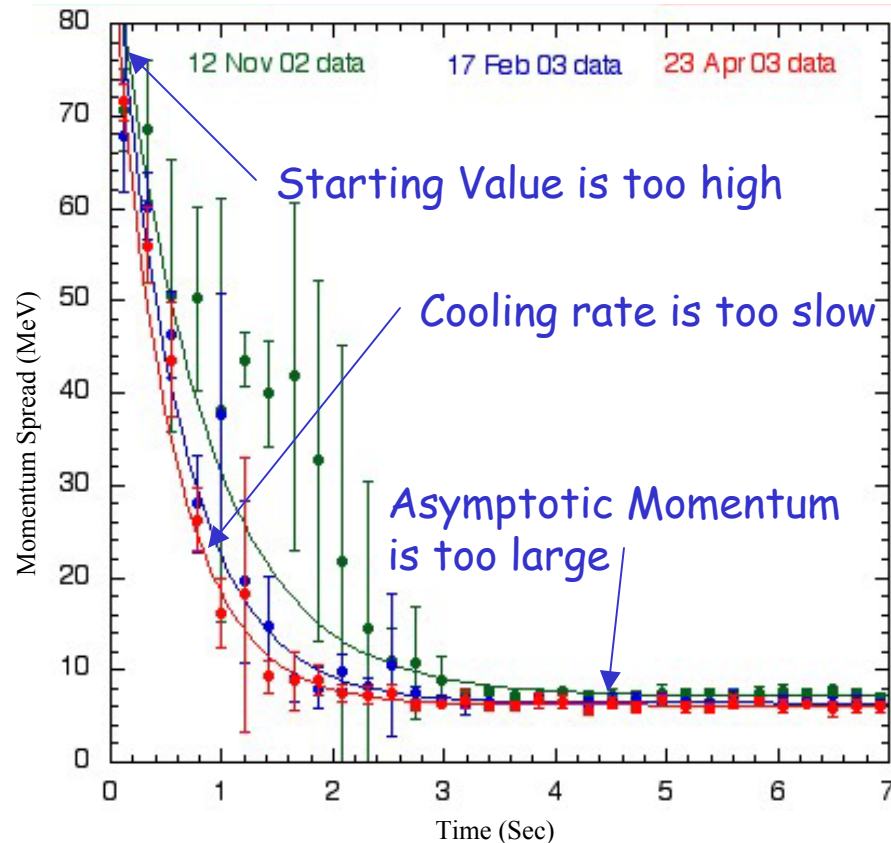
Accumulator Longitudinal Spectrum



- The Stacktail gain is limited by
 - System instabilities between the core beam and the injected beam
 - Transverse heating of the Stacktail on the core
- As the stack gets larger
 - The instability feedback path grows stronger
 - The core transverse cooling gain is reduced
- The gain of the Stacktail must be turned down to compensate
- The cycle time must increase for the lower Stacktail gain
- For a given Stacktail gain, the larger the momentum spread of the injected pulse, the longer it takes to clear the pulse from the Stacktail Deposition orbit.
 - The momentum spread coming from the Debuncher is too large.
 - Bunch length on target
 - Debuncher Cooling rate
 - Debuncher asymptotic momentum

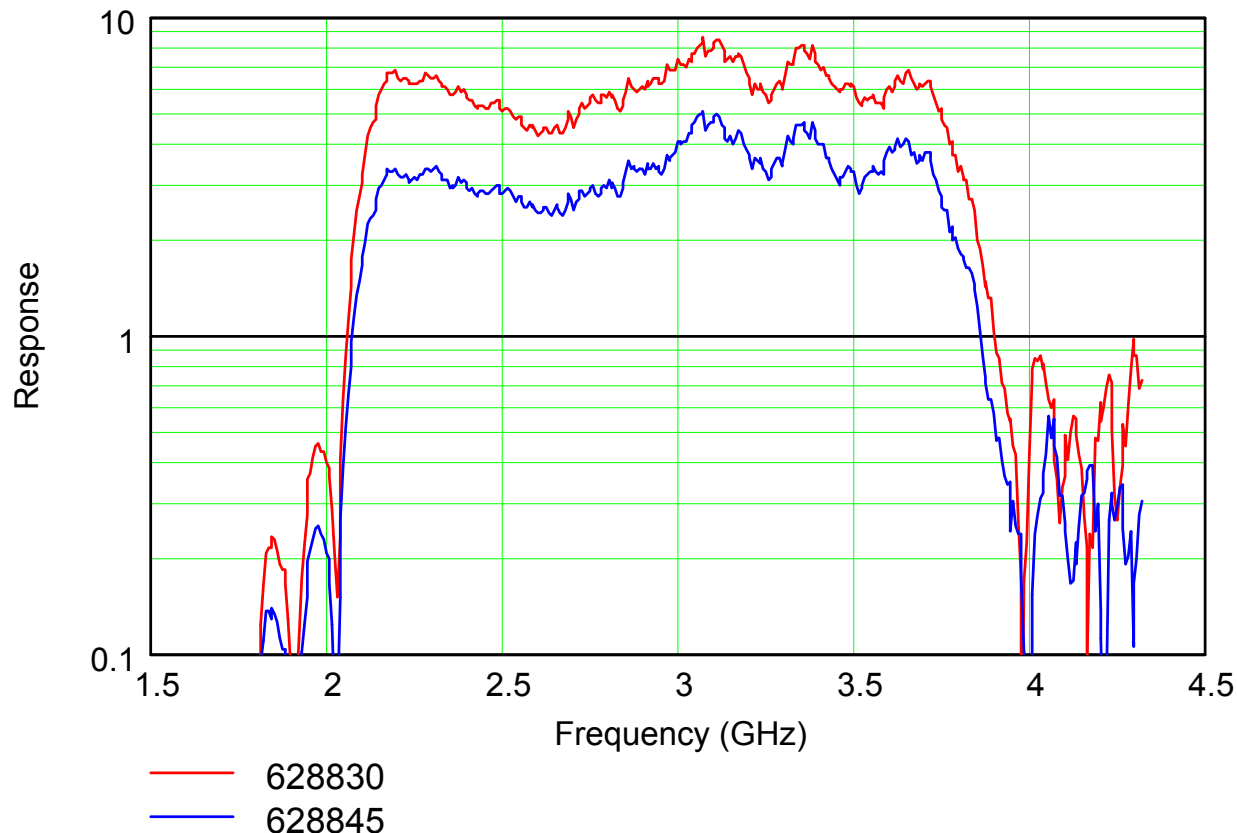
Debuncher Momentum Cooling

- Reducing the Debuncher Momentum Cooling Notch filter dispersion by 33% will permit the zero stack cycle time to be lowered from 2.4 sec to 1.7 sec
 - First iteration complete
 - Second iteration installed this shutdown



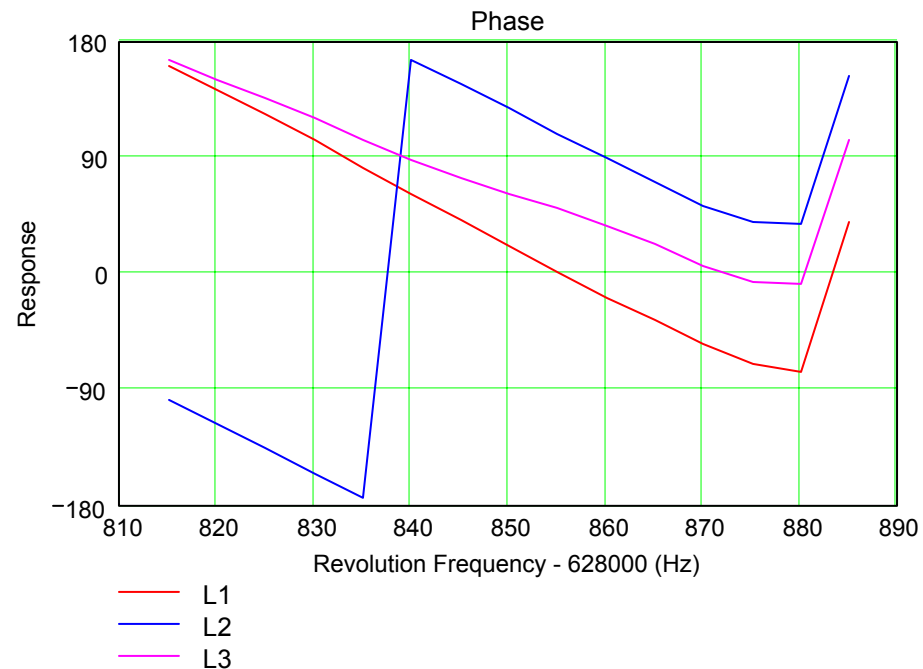
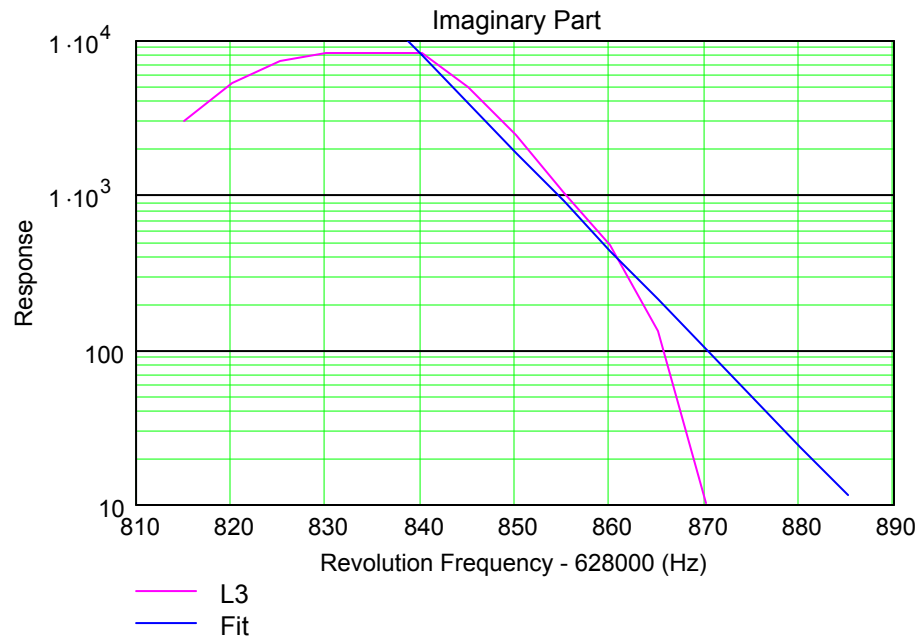
Improvements to the Stacktail

- Faster Cooling by extending lower end of band from 2.2 GHz to 1.7 GHz using new BAW filters (installed this shutdown)



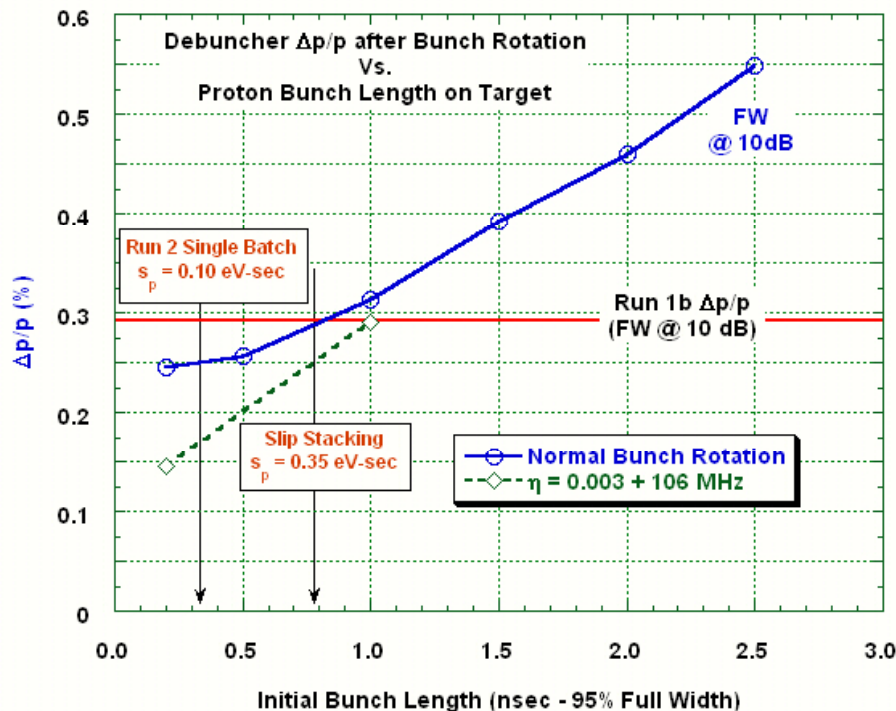
Improvements to the Stacktail

- Increase system stability by providing a better phase crossover
 - Beam transfer function measurements already done
 - Requires more analysis
 - Requires minor hardware changes



Reduce Bunch Length on the Pbar Production Target

- There is a very large longitudinal emittance blow up on the Pbar Production cycles in the Main Injector
- Effective bunch length on target is over 2 nS



- Main Injector Longitudinal Emittance control projects
 - Beam loading compensation through the entire acceleration ramp
 - Beam loading compensation is a well defined project for the Run II Upgrades
 - Beam loading already commissioned for discrete points on the ramp
 - Study time and small changes in hardware required
 - Bunch by Bunch longitudinal dampers
 - Low level electronics built
 - Cavities to be installed this shutdown
 - System to be commissioned in early FY04

Luminosity Parameters

Luminosity Parameters			
Phase	FY03	FY04	
Initial Luminosity	37.9	74.9	$\times 10^{30} \text{ cm}^{-2} \text{ sec}^{-1}$
Average Luminosity	20.7	44.4	$\times 10^{30} \text{ cm}^{-2} \text{ sec}^{-1}$
Integrated Luminosity per week	6.4	13.7	pb^{-1}
Integrated Luminosity per store	1.1	2.4	pb^{-1}
Number of stores per week	5.7	5.7	
Average Store Hours per Week	85	85	Hours
Store Length	15	15	Hours
Store Lifetime	11.0	13.0	Hours
HEP Up Time per Week	98	98	Hours
Good Week Ratio	1	1	
Shot Setup Time	2.2	2.2	Hours
	FY03	RED	

TEV Helices

TEVATRON Parameters

TEVATRON Parameters			
Phase	FY03	FY04	
Number of Protons per bunch	250	260	$\times 10^9$
Number of Pbars per bunch	24.9	37.6	$\times 10^9$
Proton Emittance	32	29	π -mm-mrad
Pbar Emittance	16	13	π -mm-mrad
σ_{proton}	0.525	0.500	meters
σ_{pbar}	0.525	0.500	meters
BetaIP	40	35	cm
Transfer Eff. To Low Beta	0.73	0.8	
Using SBD Calibration			
Back Calculated Emittances	FY03	RED	

F0 Lambertson

TEV Injection Matching

TEV Injection Coupling

TEV Helices

MI Long. Dampers

TEV Chromaticity control

Antiproton Production Parameters

Antiproton Parameters			
Phase	FY03	FY04	
Zero Stack Stacking Rate	11.3	18.0	$\times 10^{10}$ /hour
Average Stacking Rate	8.2	11.3	$\times 10^{10}$ /hour
Stack Size transferred	122.6	169.1	$\times 10^{10}$
Stack to Low Beta	89.5	135.3	$\times 10^{10}$
Pbar Production	15.0	17.0	$\times 10^{-6}$
Protons on Target	5	5	$\times 10^{12}$
Pbar cycle time	2.4	1.7	Secs.
Pbar up time fraction	1	1	
Initial Stack Size	15	15	$\times 10^{10}$
Stack Size at 1/2 Stacking Rate	150	150	$\times 10^{10}$
	FY03	RED	

Debuncher Quad Stands

Debuncher filters

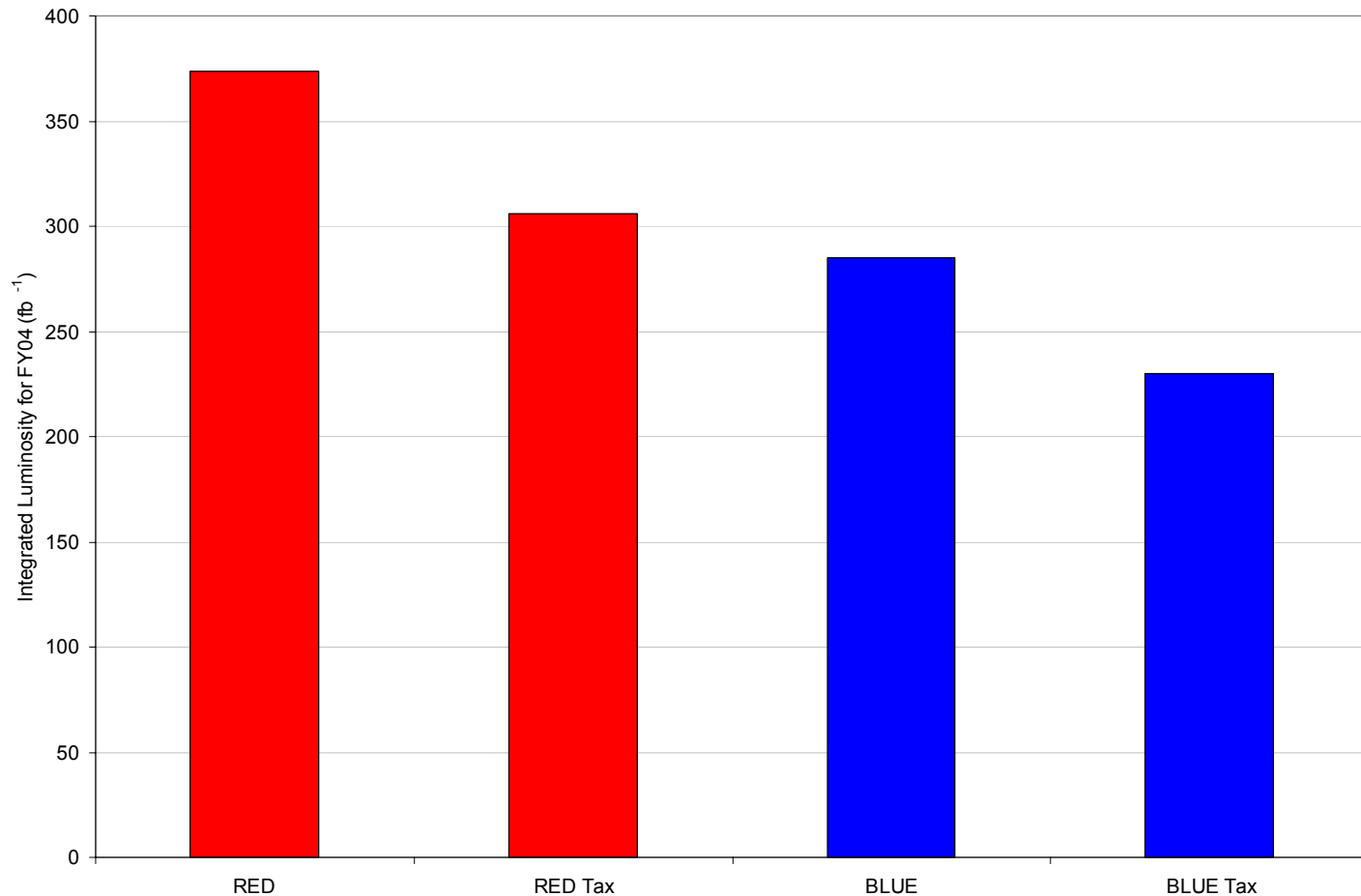
Stacktail filters

Stacktail phase crossover

MI Long. Dampers

FY04 Luminosity Parameters

FY04 Integrated Luminosity



Fiscal Year	RED	RED Tax	BLUE	BLUE Tax	
FY04	373	306	285	230	pb ⁻¹

Luminosity Parameters

	Luminosity Parameters					
Phase	FY03	FY04	FY04	FY04	FY04	
Initial Luminosity	37.9	74.9	61.9	53.4	43.3	$\times 10^{30} \text{ cm}^{-2} \text{ sec}^{-1}$
Average Luminosity	20.7	44.4	36.8	30.5	24.7	$\times 10^{30} \text{ cm}^{-2} \text{ sec}^{-1}$
Integrated Luminosity per week	6.4	13.7	11.3	9.2	7.4	pb^{-1}
Integrated Luminosity per store	1.1	2.4	2.0	1.6	1.3	pb^{-1}
Number of stores per week	5.7	5.7	5.7	5.6	5.6	
Average Store Hours per Week	85	85	85	84	84	Hours
Store Length	15	15	15	15	15	Hours
Store Lifetime	11.0	13.0	13.0	12.0	12.0	Hours
HEP Up Time per Week	98	98	98	96	96	Hours
Good Week Ratio	1	1	1	1	1	
Shot Setup Time	2.2	2.2	2.2	2.2	2.2	Hours
	FY03	RED	RED TAX	BLUE	BLUE Tax	

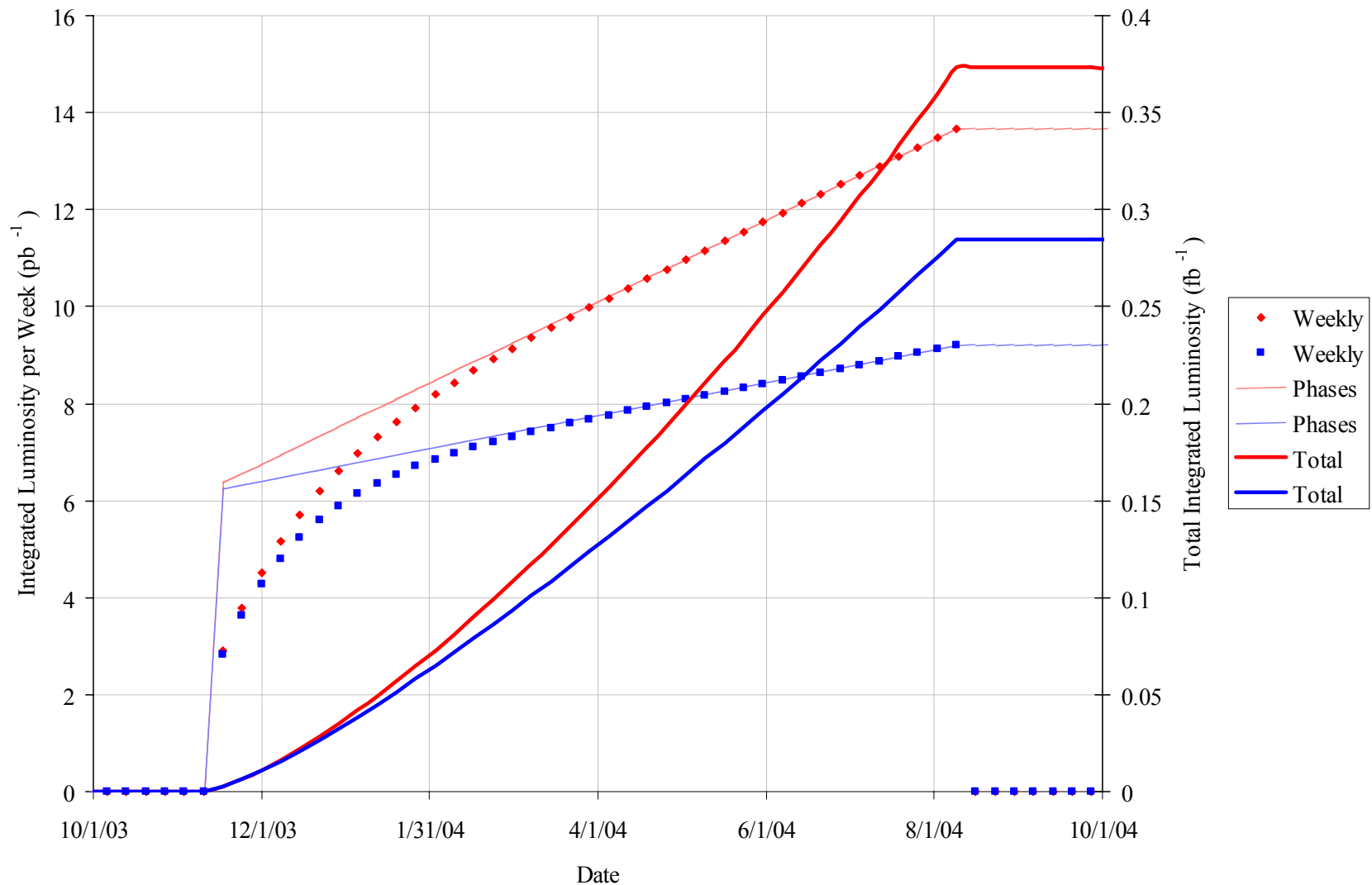
TEVATRON Parameters

	TEVATRON Parameters					
Phase	FY03	FY04	FY04	FY04	FY04	
Number of Protons per bunch	250	260	260	260	260	$\times 10^9$
Number of Pbars per bunch	24.9	37.6	31.1	30.3	24.5	$\times 10^9$
Proton Emittance	32	29	29	31	31	π -mm-mrad
Pbar Emittance	16	13	13	15	15	π -mm-mrad
σ_{proton}	0.525	0.500	0.500	0.500	0.500	meters
σ_{pbar}	0.525	0.500	0.500	0.500	0.500	meters
BetaIP	40	35	35	37	37	cm
Transfer Eff. To Low Beta	0.73	0.8	0.8	0.77	0.77	
Using SBD Calibration Back Calculated Emittances	FY03	RED	RED TAX	BLUE	BLUE Tax	

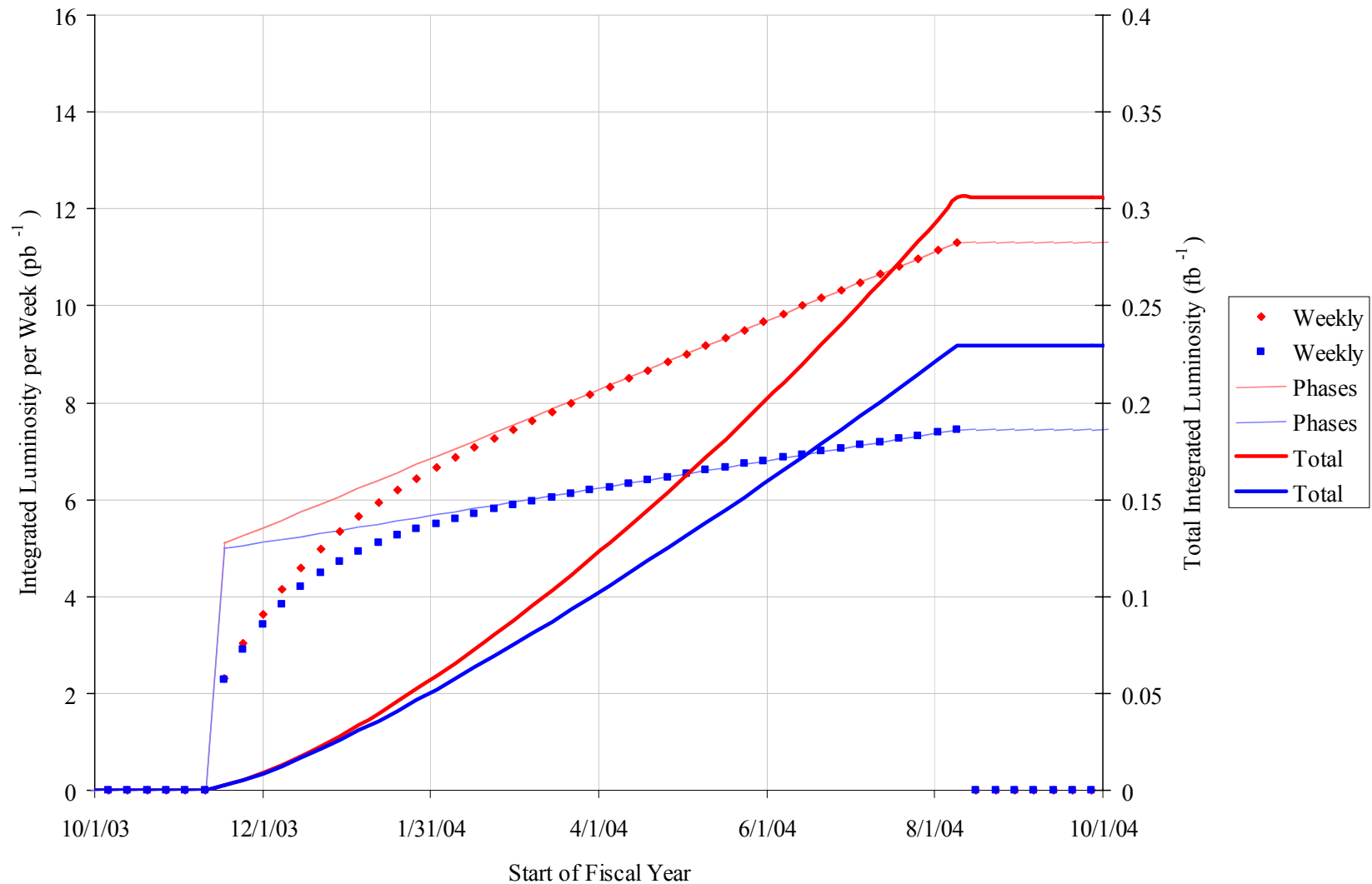
Antiproton Parameters

	Antiproton Parameters					
Phase	FY03	FY04	FY04	FY04	FY04	
Zero Stack Stacking Rate	11.3	18.0	18.0	13.7	13.7	$\times 10^{10}$ /hour
Average Stacking Rate	8.2	11.3	9.3	9.4	7.6	$\times 10^{10}$ /hour
Stack Size transferred	122.6	169.1	139.9	141.4	114.6	$\times 10^{10}$
Stack to Low Beta	89.5	135.3	111.9	108.9	88.2	$\times 10^{10}$
Pbar Production	15.0	17.0	17.0	16.0	16.0	$\times 10^{-6}$
Protons on Target	5	5	5	5	5	$\times 10^{12}$
Pbar cycle time	2.4	1.7	1.7	2.1	2.1	Secs.
Pbar up time fraction	1	1	0.75	1	0.75	
Initial Stack Size	15	15	15	15	15	$\times 10^{10}$
Stack Size at 1/2 Stacking Rate	150	150	150	150	150	$\times 10^{10}$
	FY03	RED	RED TAX	BLUE	BLUE Tax	

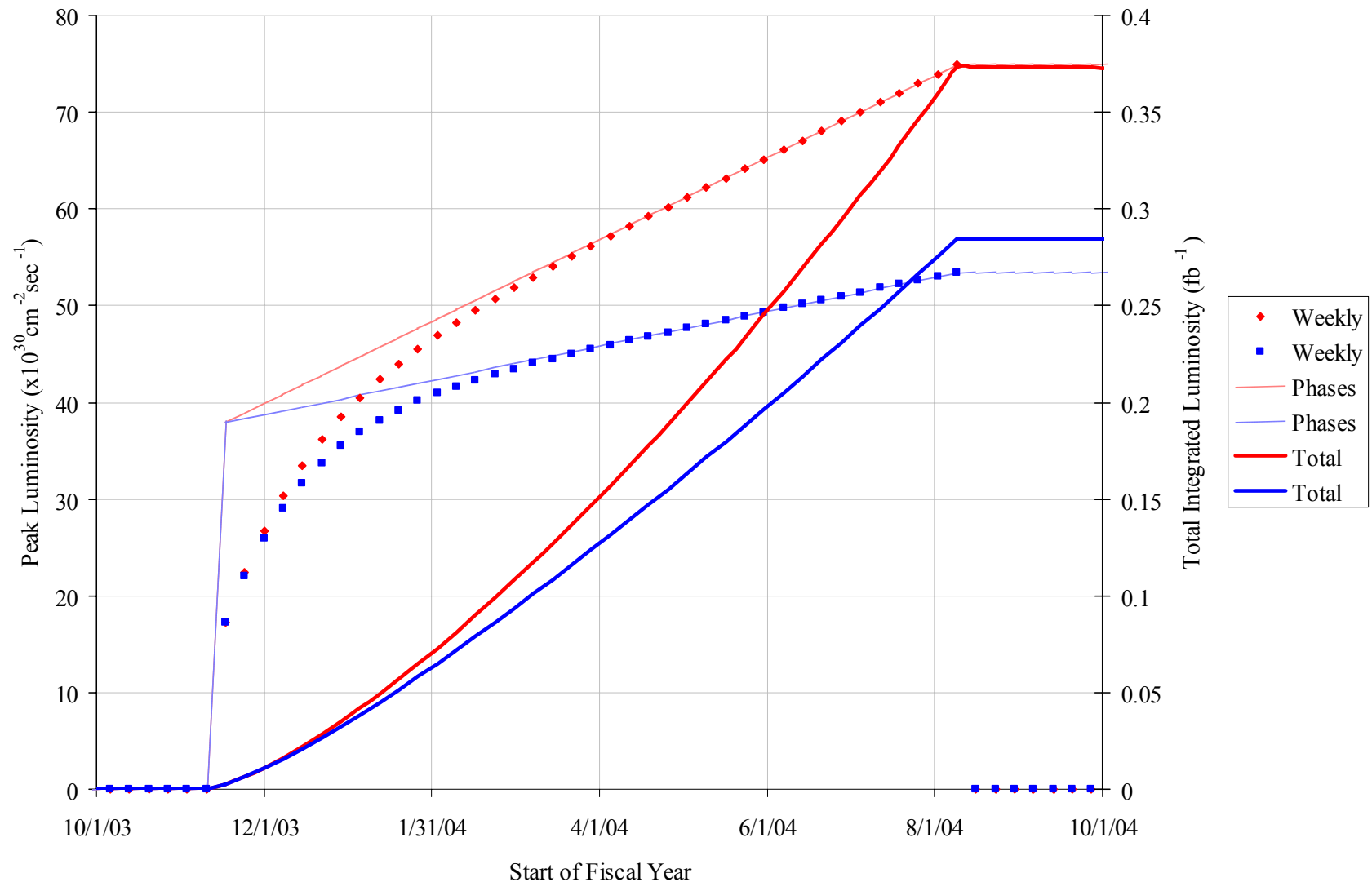
Integrated Luminosity per Week - no Pbar tax



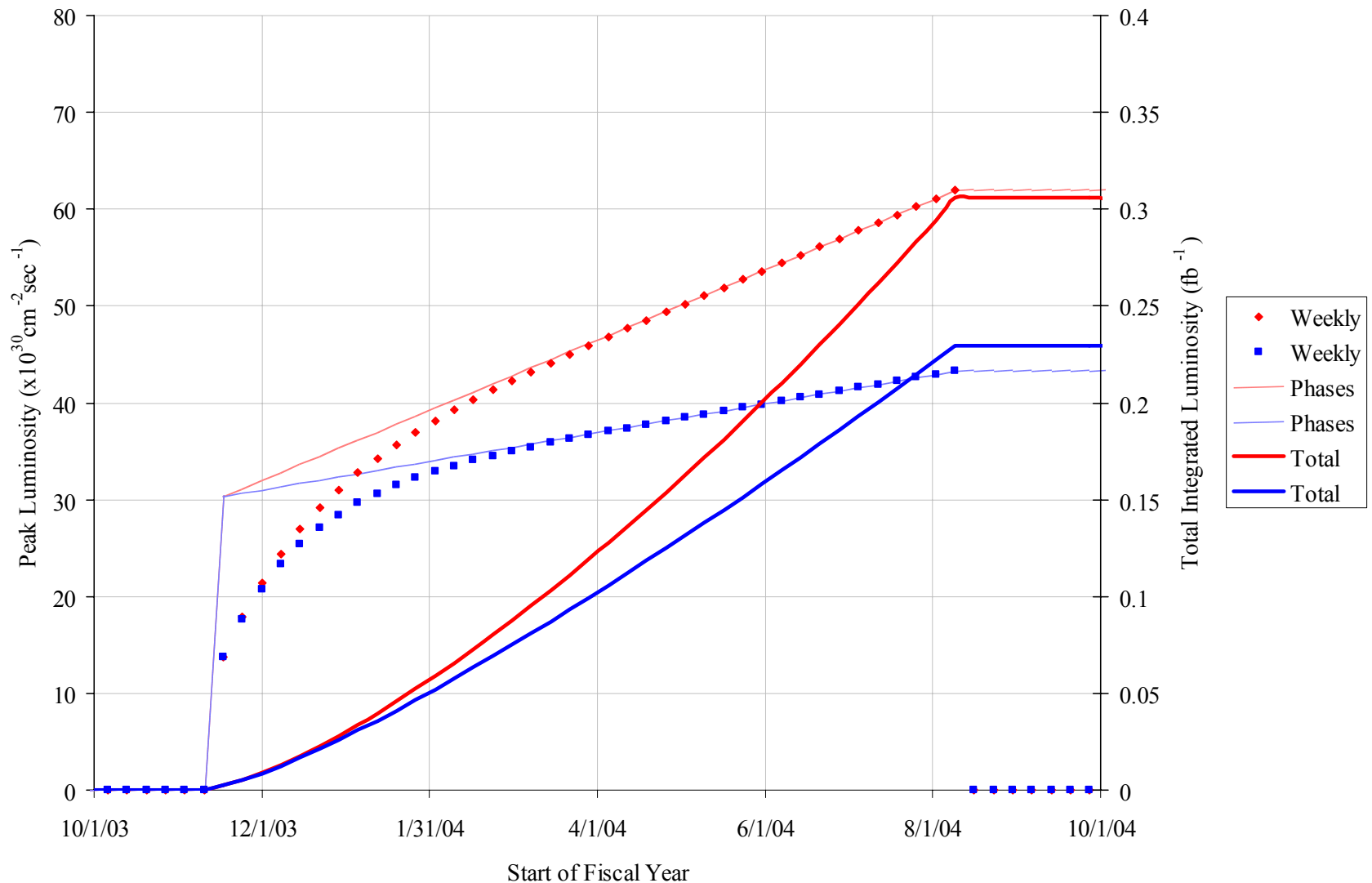
Integrated Luminosity per Week - with Pbar tax



Peak Luminosity - no Pbar tax



Peak Luminosity - Pbar tax



Operations

Startup Strategy

- Establish luminosity as quickly as possible
 - Startup tasks will focus on accelerator fundamentals
 - Orbits
 - Tunes
 - Chromaticity
 - Transfer mechanics
 - Advanced commissioning of the accelerator upgrades installed during this shutdown will await the return of routine study periods after luminosity is established.

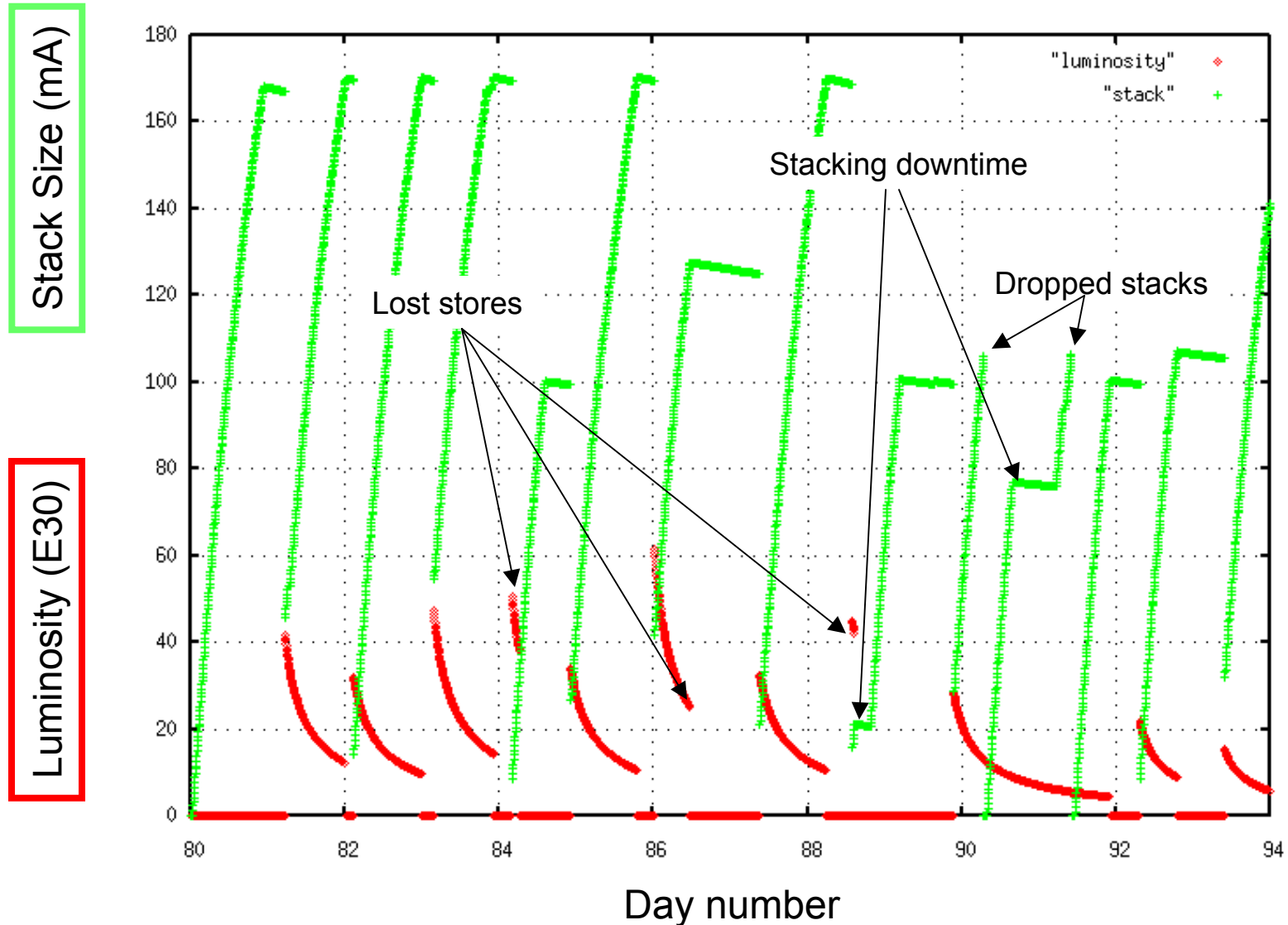
FY04 Study Strategy

- FY04 Parasitic Study Strategy
 - Recycler "Pbar Tax"
 - 25% of the Pbar stacking time line will go to Recycler commissioning
 - Uses of the tax: MI Access time, Proton events, Pbar transfers
 - Present 80% Stack size / 20% Time-line strategy
- FY04 Dedicated Study Strategy
 - A study period would begin only if the previous 14 days contained 140 hours of store time.
 - Study periods would occur twice a week.
 - Study periods will be short (8-12 hours)
 - There would be at least two stores between each study period.
 - Studies would be blocked according to themes.
 - At the end of the study block (or theme) a short write-up (TEV Note or Pbar Note) describing the results of the studies would be expected.
- Maintenance studies would occur at the discretion of the Run Coordinator.

Shot Strategy

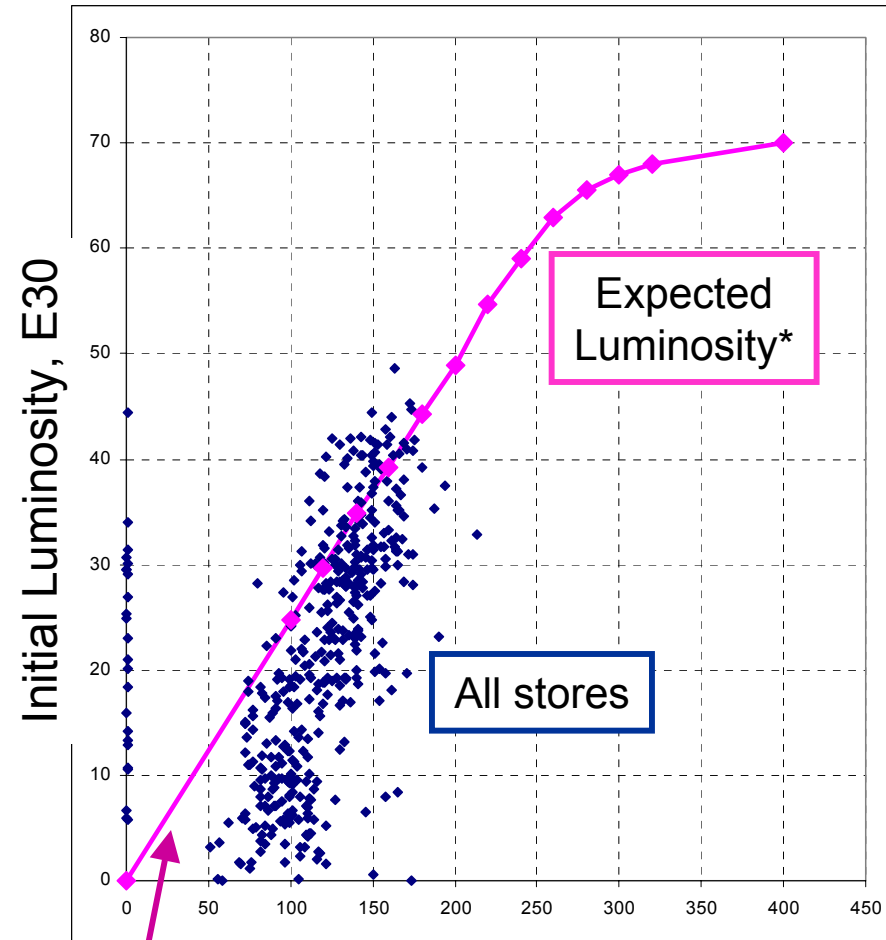
- What is the best strategy for ending a store?
 - How long should we run the stores?
 - What stack size should we shoot from
- What is the best strategy for recovering from TEV failure or a lost Pbar Stack?
 - What is the minimum stack we should shoot from.
- When is the best time to do studies?
- We are re-developing a Monte-Carlo model of the TEVATRON Complex
 - Will incorporate a realistic model of the TEVATRON based on realistic parameters obtained from SDA
 - Will model the inherent randomness of the Collider Complex
 - Downtime (based on SDA)
 - Variations on all realistic parameters (based on SDA)

Simulation of a Typical 2 Week Stacking Period



Algorithms for Ending a Store

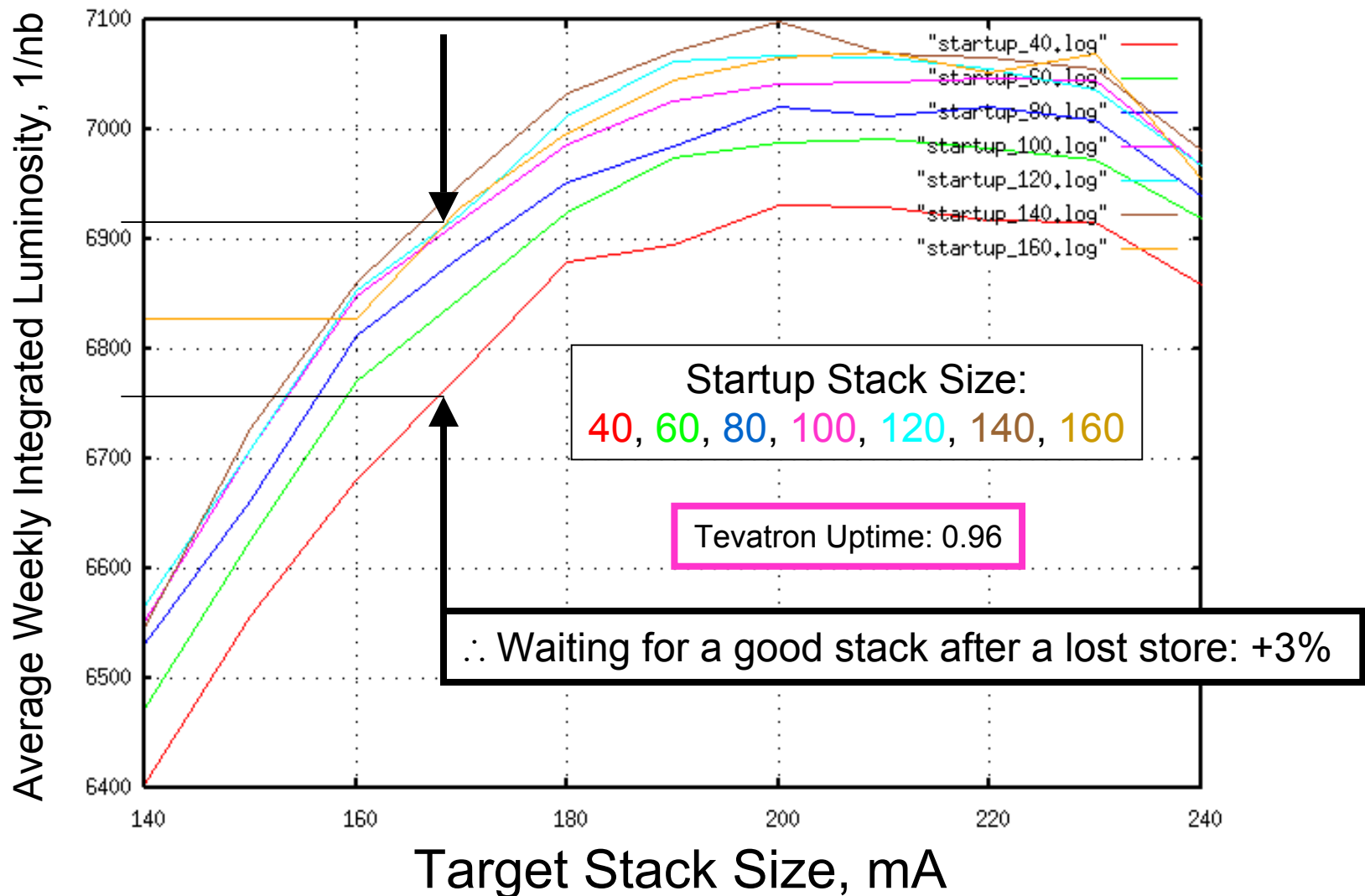
- Target Crossings
 - Stack Size
 - Store Duration
 - Integrated Luminosity
 - Minimum Instantaneous Luminosity
- Luminosity Potential
 - Comparison of “Expected” instantaneous luminosity and present instantaneous luminosity
 - When the ratio between the expected luminosity and the current luminosity exceed some constant, V .
 - When the difference exceeds constant, L .



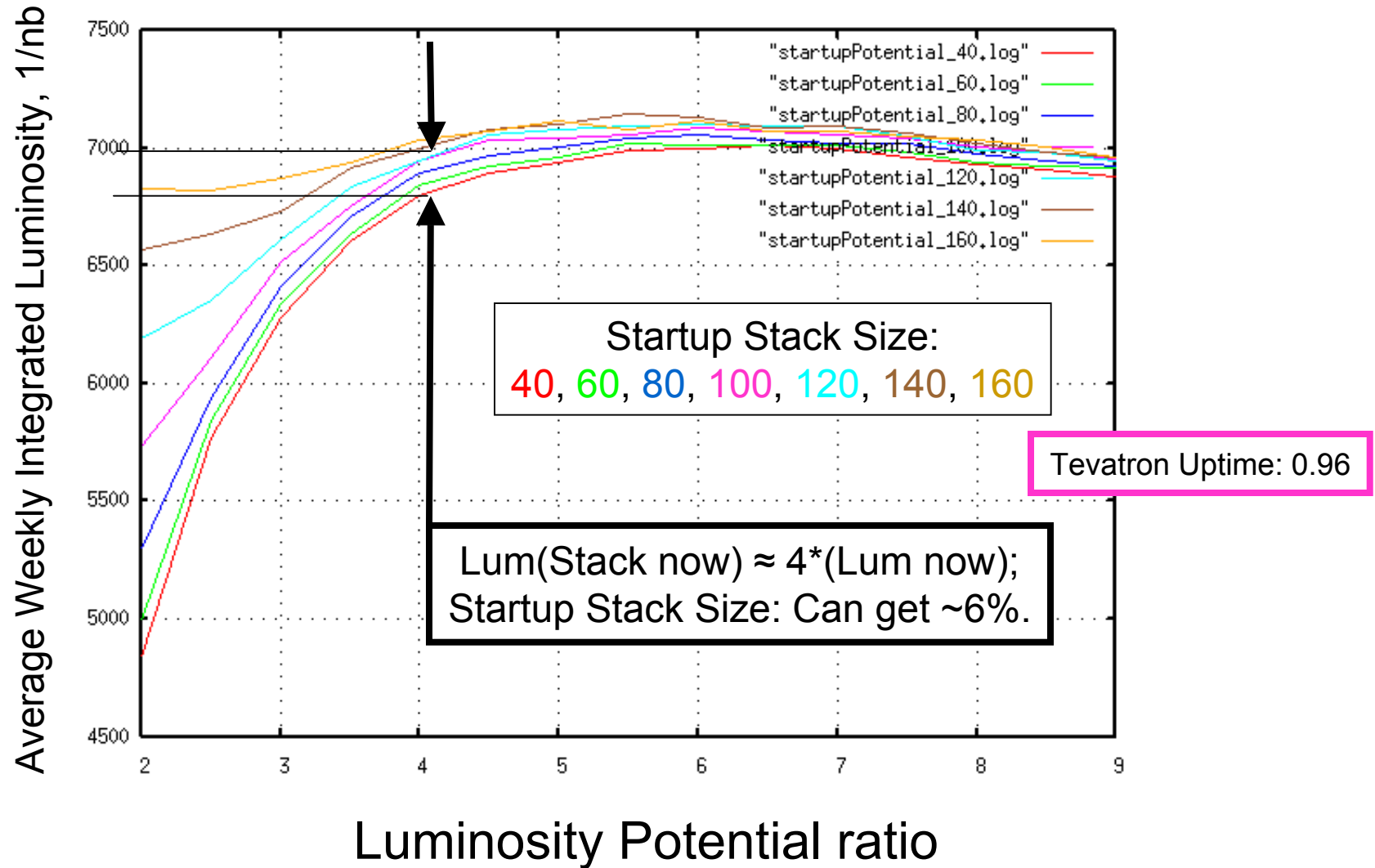
**Generated by the model; error bars (σ) \approx 20%*

Needs more confirmation from SDA

Target Stack Size and Recovery from TEV Failure



Example of Startup Stack Size and Luminosity Potential Ratio



Accelerator Coordination

Accelerator Coordination

- The Collider is commissioned
 - We are in an operating phase with periodic upgrades to be installed during shutdowns.
 - The handling of Collider operations and downtime has become routine.
- The competition for beam, study time, and resources between the Collider and external beam lines will increase significantly in FY04
 - MiniBoone is operational
 - SY120 will be operational in FY04
 - NUMI will start commissioning in early FY05

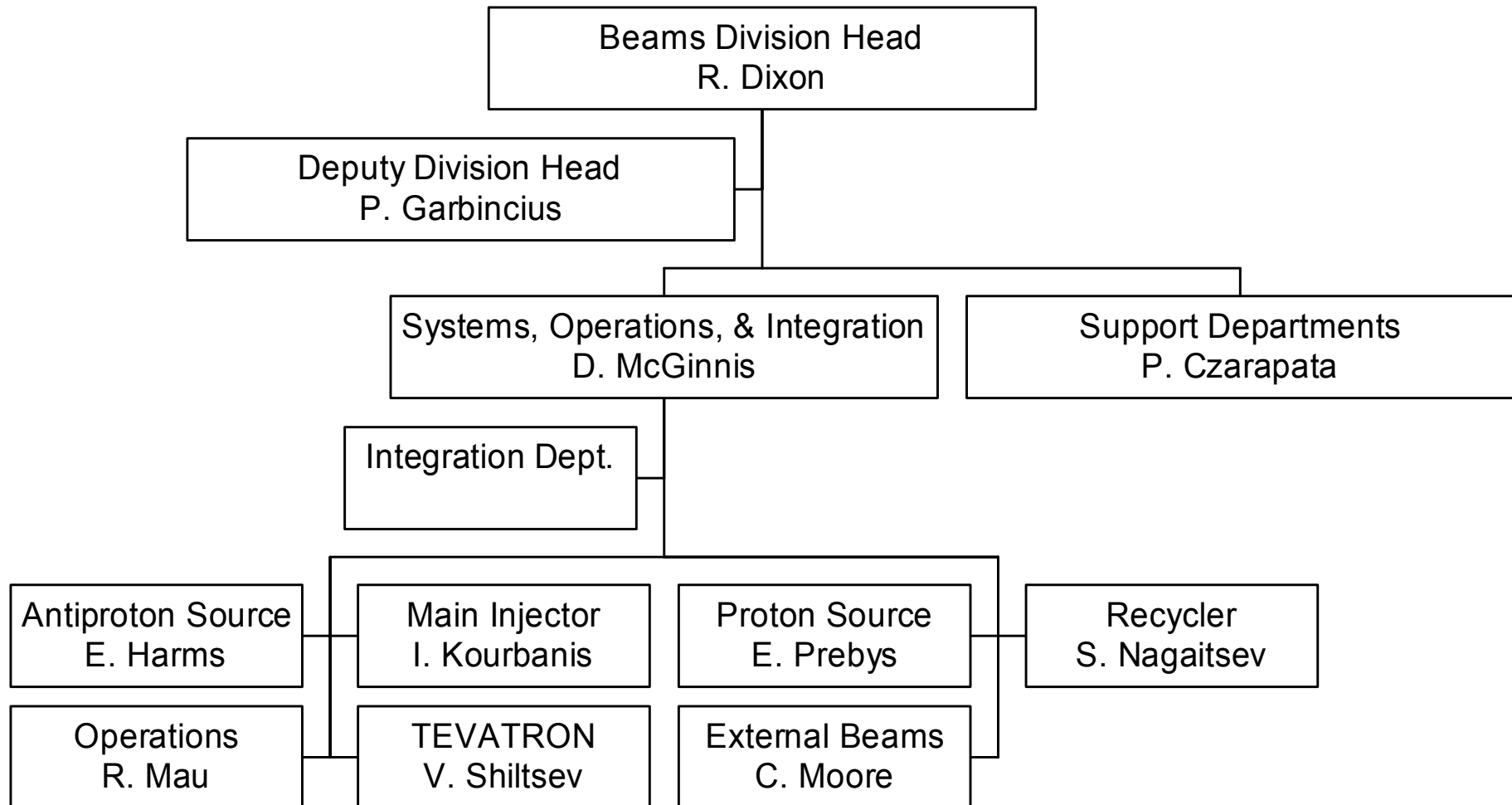
Requirements on Accelerator Coordination in FY04

- Provide long-term continuity for operational goals, strategy and monitoring.
- Improve/clarify assignments of responsibility for
 - study strategy and coordination
 - machine parameter targets
 - shot strategy
- Provide coherence across individual machine coordinators

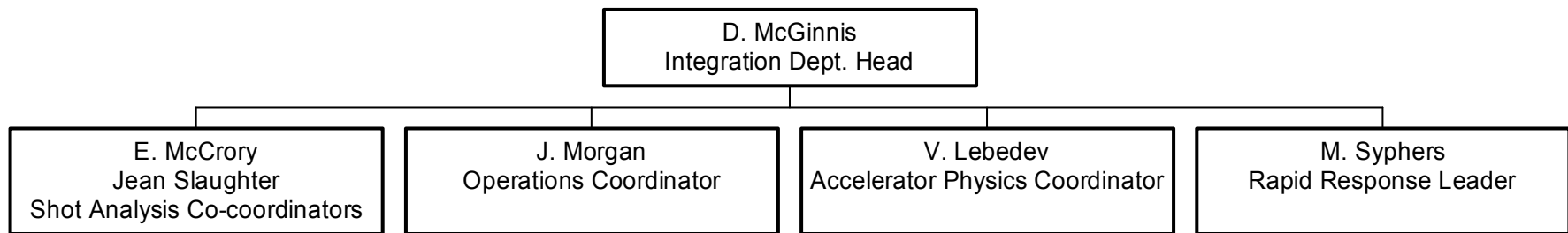
Accelerator Coordination in FY04

- The task for coordinating the operations of the accelerators in FY04 will be the permanent responsibility of the new Integration Department.
- The leader of the Integration Department will be the Associate Division Head for Systems, Operations, and Integration.
- This Integrations Department will be divided into four wings
 - Operations Coordination
 - Shot Analysis and Strategy Coordination
 - Accelerator Physics and Accelerator Studies Coordination
 - Rapid Response Team

Systems, Operations, & Integration Organization



Integration Department Organization



The Accelerator Operations Coordination Team

- Accelerator Operations is coordinated by a team from the Integration Department
 - Leader - Integration Dept. Head - Dave McGinnis
 - Operations Coordinator - Jim Morgan
 - Shot Analysis Coordinator - Elliott McCrory & Jean Slaughter
 - Accelerator Physics Coordinator - Valerie Lebedev
 - Rapid Response Team Leader - Mike Syphers
- Responsibilities of the Coordination Team
 - Defines guidelines for the Operations dept.
 - When to shoot, When to fix things, When to call in experts, etc.
 - Defines shot strategy
 - Defines and implements accelerator physics strategy and an integrated view across machines
 - Defines study strategy
 - Leads shot data analysis
 - Data Quality
 - Data interpretation
 - Sets priorities of instrumentation projects
 - Interfaces with the Directorate and the Experiments
 - Makes decisions for unusual operational situations

Coordination Team

- **Leader - Dave McGinnis**
 - Runs the daily Accelerator Integration Meeting (presently at 8:30 am)
 - Decides on study and shot strategy for week
 - Interfaces with Directorate and Experiments
 - All Exp. Meeting
 - 9:30 Meeting with Experiments
 - Responsible for handling unusual operational situations
 - Will delegate to others in the team to ensure coverage.
- **Operations coordinator - Jim Morgan**
 - Runs the 9:00 meeting.
 - Shares responsibility for handling unusual operational situations.
 - Develops and oversees operational guidelines for the Operations Dept.
 - Evaluates and oversees operational policies of the Systems Depts.
 - Monitors peak operating performance of the accelerators
- **Shot Coordinator - Elliott McCrory & Jean Slaughter**
 - Responsible for the operational model of the accelerator complex
 - Develops guidelines for shot strategy based on SDA data
 - Responsible for physics analysis of shot data
 - Oversees the development of shot data analysis tools
 - Responsible for the integrity of shot data
 - Shares responsibility for handling unusual operational situations.

Coordination Team

- Accelerator Physics and Study Coordinator - V. Lebedev
 - Responsible for the physics model of the accelerator complex.
 - Develops and prioritizes the study plan for the accelerator complex.
 - Monitors the study proposals and write-ups of the Systems departments.
 - Prioritizes the accelerator physics issues of the accelerator complex.
 - Coordinates the accelerator physics task forces
 - Coordinates the Thursday Run II Accelerator Physics Meeting along with Jean Slaughter
- Rapid Response Team - Mike Syphers
 - Used to solve pressing operational or accelerator physics problems that have a life span of ~3-6 months
 - Focuses on one or two problems at a time (i.e. Injection matching into the TEV, Bunch length in the Main Injector, NUMI commissioning)
 - Consists of a strong group of accelerator physicists in the division - membership will be dynamic
 - Deployment of Rapid Response Team controlled by the Coordination Team

Summary

- In FY03, we focused on
 - Increasing the proton intensity (250×10^9 /bunch)
 - Increasing the transmission efficiency of pbars to low beta (73%)
- Our goal in FY04 is to increase the potential for integrating luminosity by a factor of 2 over FY03. This increase will be done mainly by increasing:
 - Zero stack stacking rate
 - Transmission efficiency of pbars to low beta
- The vast majority of hardware needed to accomplish the FY04 goals was installed by the end of this shutdown.
- The Collider is commissioned
 - We are in an operating phase with periodic upgrades to be installed during shutdowns.
 - With an integrated accelerator study philosophy and an operations model of the complex, we will balance
 - Integrating luminosity
 - Accelerator studies
 - Commissioning the Recycler